Dimensional Crossover in Spin-1 Heisenberg Antiferromagnets: a Quantum Monte Carlo Study

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We present a quantum Monte Carlo study of the spin-1 Heisenberg antiferromagnet on a cubic lattice. The stochastic series expansion method is used to calculate equilibrium thermodynamic variables in the presence of an external magnetic field. In particular, the low temperature magnetization curve is investigated in the quasi-one-dimensional (Q1D), quasi-two-dimensional (Q2D), and three-dimensional (3D) limits. Starting from the 3D limit, the Q1D (Q2D) limit is achieved by reducing the in-plane (out-of-plane) spin coupling strength towards zero. In the Q1D limit, a Haldane gap appears in the magnetization curve at low magnetic field. Additionally, near the saturation field the slope of the magnetization curve increases substantially, approaching the infinite-slope behavior of a one-dimensional spin-1 chain. A similar (though less pronounced) effect is seen in the Q2D limit. We also study the effect of uniaxial single-ion anisotropy on the magnetization curve for Q1D and Q2D systems. Our results will be important in understanding the field-induced behavior of a class of low-dimensional Ni-based quantum magnets.